The origin of the Kheis Terrane and its relationship with the Archean Kaapvaal Craton and the Grenvillian Namaqua Province in southern Africa

by

Hermanus Stephanus van Niekerk

THESIS

Presented in fulfilment of the requirements for the degree of

PHILOSOPHIAE DOCTOR

in

GEOLOGY

in the

FACULTY OF SCIENCE

of the

UNIVERSITY OF JOHANNESBURG

Promoter

Prof. N.J. Beukes

Co-Promoter

Prof. C.A. Smit

January 2006

Declaration

I declare that this is my own original work, conducted under supervision of Profs. N.J. Beukes and C.A. Smit. It is submitted for the degree Doctor of Philosophy at the Faculty of Science at the University of Johannesburg, Johannesburg. No part of this research has been submitted in the past, or is being submitted, for a degree or examination at any other University

Herman S. van Niekerk

Acknowledgements

"Ten-twenty-nine, Ten-thirteen, Ten-thirty-six…."

I wish to thank my supervisor, Professor Nic Beukes, for not only being my supervisor in this study, but also for being someone we all look up to and who's enthusiasm is an inspiration to all of us. I would like to thank him for all his support, guidance, and also for being there for me when it was really necessary. I would also like to thank Professor Andre Smit for his supervision and all the geological discussions.

I would like to thank my parents, for their support throughout my studies, and for their guidance and advice in my life. I would especially like to thank my father who made me change my career path, even though he knew how difficult it would be for me….and my mother for always remaining optimistic.

I am also grateful to René Boshoff for her support and friendship during the last years of this study. I would also like to thank her for helping with the formatting of this thesis.

I would also like to thank Professor Jens Gutzmer for his continuous motivation, encouragement, friendship and helpful discussions, not only during this study, but also in all other matters of geology and life.

Furthermore I am deeply indebted to Dr Richard Armstrong, his family and his co-workers, including Dr Mark Fanning, for their friendship and hospitality and in particular for making the time available for me to conduct my research on the SHRIMP's at the Research School of Earth Science of the Australian National University. I would like to thank them especially for the time they so urgently made available to me during my first visit to Australia: This will never be forgotten. I thank Dr Paulo Vasconcelos for providing the Ar-Ar data and also Dr Emil Weder for contributing to the interpretation of the aeromagnetic images.

I would like to thank Dr Bruce Eglington for making his geochronological database "DateView" available to aid in the determination of possible source areas for the detrital zircon grains analysed in this study.

Two families played a big part in the completion of this thesis. I which to thank the Schoeman's of Olifantshoek for their friendliness, hospitality and continuing friendship, and for allowing me to share so much of their daily lives with them. My sincere thanks also go to the Hanekom family form Groblershoop. I would like to thank them for taking me into their house for so long and for their encouragement and support during the long and very hot field seasons. And a special "thank you" to "Oom Bertie", for making me "carry on" even when the heat was unbearable.

Furthermore I would like to thank the staff of the Geology Department of the University of Johannesburg for their continuous support and friendship throughout my studies. I would also like to thank the staff of the Analytical Facility of the Faculty of Natural Science (Spectrau) of the University of Johannesburg for their help and especially Dr Willie Oldewage for his support and also for making the necessary "computing power" available. I am also indebted to the Faculty of Natural Science of the University of Johannesburg and in particular the previous Dean of Science, Prof Dirk van Reenen, for his continuous support.

I would also like to thank my friends, not only here at the University of Johannesburg, but also elsewhere, for their friendship and support and interesting discussions and also for making life more interesting.

Also thank you to my dear friends Hunters, Crispi, Rascal, Kallisto and George for keeping me company through the long nights.

Last but not least, I would also like to thank my old friend Chris Pope for 16 long years of friendship, camaraderie and support, not only during our time together as fire-fighters, but also as a close friend always encouraging me to complete this thesis.

Abstract

The tectonic history of the Kheis Terrane and its relationship with the Namaqua-Natal Metamorphic Province (NNMP) along the western margin of the Kaapvaal Craton were the focus of this study. Major issues addressed in this study are the origin and timing of formation of the Kheis Terrane and the recognition and definition of terrane boundaries in the area. Results of detailed measured sections across the Kheis Terrane, heavy mineral provenance studies, $^{40}Ar/^{39}Ar$ analyses of metamorphic muscovite, U-Pb SHRIMP dating of detrital zircon grains from 12 samples from the Kheis- and Kakamas Terranes and one igneous body from the Kakamas Terrane are presented.

A new stratigraphic unit, the Keis Supergroup, comprising the Olifantshoek-, Groblershoop- and Wilgenhoutsdrif Groups, is defined. The base of the Keis Supergroup is taken at the basal conglomerate of the Neylan Formation. The Mapedi- and Lucknow Formations, previously considered part of the Olifantshoek Group, are now incorporated into the underlying Transvaal Supergroup. The Dabep Fault was found not to represent a terrane boundary. Rather, the Blackridge Thrust represents the boundary between the rocks of the Kheis Terrane and the Kaapvaal Craton.

Provenance studies indicate that the rocks of the Keis Supergroup were deposited along a passive continental margin on the western side of the Kaapvaal-Zimbabwe Craton with the detritus derived from a cratonic interior. Detrital zircon grains from the rocks of the Keis Supergroup of the Kheis Terrane all gave similar detrital zircon age populations of ~1800Ma to ~2300Ma and ~2500Ma to ~2700Ma. The Kaapvaal Craton most probably never acted as a major source area for the rocks of the Keis Supergroup because of the lack of Paleo- to Mesoarchean zircon populations in the Keis Supergroup. Most of the detrital zircon grains incorporated into the Keis Supergroup were derived from the Magondi- and Limpopo Belts and the Zimbabwe Craton to the northeast of the Keis basin.

The rock of the Kakamas Terrane was derived from a totally different source area with ages of ~1100Ma to ~1500Ma and ~1700Ma to ~1900Ma which were derived from the Richtersveld- and Bushmanland Terranes as well as the ~1166Ma old granitic gneisses of

the Kakamas Terrane. Therefore the rocks of the Kheis- and Kakamas Terranes were separated from each other during their deposition.

Detrital zircon populations from the Sprigg Formation indicate that it this unit was deposited after the amalgamation of the Kheis- and Kakamas Terranes and therefore does not belong to the Areachap Group.

Results provide clear evidence for a tectonic model characterised by the presence of at least two Wilson cycles that affeected the western margin of the Kaapvaal Craton in the interval between the extrusion of the Hartley lavas at 1.93Ga and the collision with the Richtersveld tectonic domain at ~1.13Ga.

According to the revised plate tectonic model for the western margin of the Kaapvaal-Zimbabwe Craton, the Neylan Formation represents the initiation of the first Wilson Cycle, with rifting at ~1927Ma ago, on the western margin of the Kaapvaal-Zimbabwe Craton. The metasedimentary rocks of the Olifantshoek Group were deposited in a braided river environment which gradually changed into a shallow marine environment towards the top of the Olifantshoek Group in the Top Dog Formation. The metasedimentary rocks of the Groblershoop Group were deposited in a shallow, passive or trailing continental margin on the western side of the Kaapvaal-Zimbabwe Craton.

The rocks of the Wilgenhoutsdrif Group overlie the Groblershoop Group unconformably. This unconformity is related to crustal warping as a volcanic arc, represented by the metavolcanics of the Areachap Group, approached the Kaapvaal-Zimbabwe Craton from the west. The rocks of the Keis Supergroup were deformed into the Kheis Terrane during the collision of the Kaapvaal-Zimbabwe Craton, Areachap Arc and the Kgalagadi Terrane to form the Kaapvaal-Zimbabwe-Kgalagadi Craton. This event took place sometime between 1290Ma, the age of deformed granites in the Kheis Terrane and 1172Ma, the initiation of rifting represented by the Koras Group. This is supported by $^{40}Ar/^{39}Ar$ analyses of metamorphic muscovite from the Kheis Terrane that did not provide any evidence for a ~1.8Ga old Kheis orogeny (an age commonly suggested in the past for this orogeny). This collisional event resulted in the deformation of the rocks of the Keis Supergroup into the Kheis Terrane sometime between 1290Ma and 1172Ma.

The second Wilson cycle was initiated during rifting along the Koras-Sinclair-Ghanzi rift on the Kaapvaal-Zimbabwe-Kgalagadi Craton at ~1172Ma. It was followed soon after by the initiation of subduction underneath the Richtersveld cratonic fragment at ~1166Ma after which the rocks of the Korannaland Group were deposited. The closure of the oceanic basin between the Kaapvaal-Zimbabwe-Kgalagadi Craton and the Richtersveld cratonic fragment occurred about 50Ma later (~1113Ma, the age of neomorphic muscovite in the metasedimentary rocks of the Kakamas Terrane) and resulted in the large open folds characterising the Kheis terrane and NNMP.

Detrital zircon populations in the Sprigg Formation show that this formation does not belong to the Areachap Group and that it was deposited after the closure of the oceanic basin between the Kaapvaal-Zimbabwe-Kgalagadi Craton and the Richtersveld cratonic fragment at ~1113Ma.

The Areachap Group can be extended towards the north and into Botswana along the Kalahari line where it forms the boundary between the Kaapvaal-Zimbabwe Craton to its east and the Kgalagadi Terrane to its west. The Areachap Terrane is thus related to the collision of the Kaapvaal-Zimbabwe Craton and Kgalagadi Terrane and was deformed a second time during the oblique collision of the Richtersveld cratonic fragment with the combined Kaapvaal-Zimbabwe-Kgalagadi Craton. The extension of the Areachap Group to the north along the Kalahari line opens up new exploration prospects for Copperton-type massive sulphide deposits underneath the Kalahari sand.